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# THE USE OF TWO NEW SOIL FUMIGANTS, D-D and EDB, FOR WIREWORM CONTROL IN CALIFORNIA

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The use of fumigants for controlling wireworms is not a new practice; calcium cyanide, carbon disulfide, chloropicrin, dichloroethyl ether, paradichlorobenzene, naphthalene, and others have been tried with varying degrees of success. No practical and economical method of control was possible, however, until the appearance of D-D (dichloropropane-dichloropropene) and later of EDB (ethylene dibromide), together with the development of new equipment for applying these chemicals.

The information in this leaflet is based on experiments and commercial applications conducted primarily in the Salinas and Sacramento valleys since 1943. In other parts of the state, the dosages may sometimes have to be modified because of soil texture, soil temperature, soil moisture, or other local conditions.

Wireworms, the larvae or immature active stages of Elateridae, or click beetles, are among the most destructive insects, causing damage to truck, field, and flower crops. They feed on the germinating seed and later on the underground parts of the plants (fig. 1). The name "wireworm" describes their smooth, shiny bodies (fig. 2). The California wireworms of economic importance are approximately 1 inch long. Members of the genus *Limonius* comprise one of the most destructive groups, including the sugar-beet wireworm, *Limonius californicus* Mann., the Pacific Coast wireworm, *L. canus* Lec., and the western field wireworm, *L. infuscatus* Mots. This group causes damage primarily to crops on cultivated land, especially where irrigation is practiced. The two species last mentioned are found more often in lighter types of soil, whereas the sugar-beet wireworm seems to prefer heavier types. In southern California the wireworm, *Melanotus longulus* Lec., often causes considerable injury to beans and other crops. Damage may also be done by other wireworms in the genera *Aeolus*, *Cardiophorus*, and *Anchastus*.

The eggs of the irrigated-land wireworm are pearly white and nearly round (fig. 3). They are laid during the spring in damp soil, usually in the upper 6 inches. In 3 to 4 weeks the wireworms emerge. These small worms do little harm until their second year, at which time under

favorable conditions a few can transform to pupae, remain in their pupal cells until the following spring, then emerge as adult beetles. Usually, however, the worms require three to five years in which to become beetles; under certain unfavorable conditions the time may be even longer. The adult females, emerging in the spring, proceed to mate and soon to burrow into



Fig. 1.--Sugar-beet wireworms feeding on roots of lettuce (left); undamaged roots (right)

the soil to deposit 50 to 300 eggs apiece. This type of life history results in a considerable overlapping of generations, so that wireworms of all sizes may be found in a single field.

## Dichloropropane-Dichloropropene (D-D)

D-D<sup>2</sup> is a dark liquid, consisting chiefly of

<sup>2</sup>The chemical used in this investigation was supplied by the Shell Chemical Company of San Francisco, California.

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1,2-dichloropropane and 1,3-dichloropropene (in the ratio of 1 part to 2 parts). It also contains minor percentages of other lighter and heavier hydrocarbons, saturated and unsaturated.

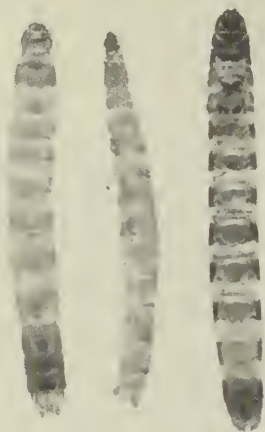


Fig. 2.--Wireworms, or the larval stage of a Limonius species. (x 3.)



Fig. 3.--Eggs of the Pacific Coast wireworm, Limonius canus Lec. (x 15.)

The typical physical properties of the liquid are as follows:

Color and state . . . . .	dark liquid
Boiling range, degrees centigrade . .	95-150
Specific gravity . . . . .	1.2
Pounds, per U.S. gallon . . . . .	10
Vapor pressure, millimeters of mercury (25°C) . . . . .	40
Flash point, degrees Fahrenheit . . .	75-85
Solubility in water, per cent weight (approximate) . . . . .	0.2

The chief toxic agent of the mixture is the 1,3-dichloropropene fraction; but there is also some evidence of synergistic action between this fraction and the other components, which include 1,2-dichloropropane and other chlorinated compounds.

D-D was first used in the Hawaiian Islands against nematodes, but has since been found to control wireworms, garden centipedes, certain other soil insects, and certain soil pathogens. In California, experiments dealing with wireworms have been restricted chiefly to beans, carrots, lettuce, and tomatoes, although in the Salinas Valley and certain other areas the land is double-cropped during the winter to broccoli, celery, or other vegetables, which, because of the inactivity of the wireworms, are not injured at that season.

D-D can be applied to garden plots, seedbeds, or greenhouses by means of hand applicators like the one shown in figure 4. The set screw on the plunger can be set to deliver any amount of fumigant desired. At 12-inch spacings, about 3.5 milliliters (cubic centimeters) are needed to give a dosage of 400 pounds per acre; at 18-inch spacings, about 8 milliliters (1 fluid ounce = 29.6 milliliters). For a dosage of 200 pounds per acre, these amounts can be halved; and for 600 pounds, one half more can be added. The applicator, after being used, should be thoroughly rinsed with oil, gasoline, or kerosene; and the projection point, spring, and ball should be removed, cleaned, and stored until the machine is needed again.



Fig. 4.--Applying soil fumigants by means of a hand-operated weed gun.

For field application a trailer applicator has been designed to apply D-D at any desired dosage (fig. 5). The trailer is usually pulled by a track-laying tractor or a cultivator. In using a cultivator, a hitch can be fastened to the rear tool bar to which the trailer applicator is attached. The cost of the chemical usually includes the cost of application, which, at current prices, is 20 cents per pound for the first 200 pounds and 17.5 cents for each additional pound.



Fig. 5.--Trailer applicator applying D-D soil fumigant on a large scale.  
(Photograph, courtesy of Shell Chemical Company.)

At the 400-per-acre dosage, this amounts to \$75 per acre.

Tests conducted in the Salinas and Sacramento valleys since 1943 indicate that the 400-pound (40-gallon) treatment is the most satisfactory from the standpoint of crop yields, wireworm control, and cost (fig. 6). To achieve a perfect kill one often has to use 600 pounds per acre; but the per cent of wireworm kill varies according to soil texture, soil moisture, soil temperature, and many other factors. The soil should be in good friable condition, ready for planting, but not ridged up (listed), and not too wet or too dry. The soil temperature at an 8-inch level should not be below 50°F and preferably should be higher. The interval of spacing should be 12 to 15 inches, and the fumigant should be drilled to a depth of 6 to 8 inches. If the fumigant is applied at a depth of 6 to 8 inches it will diffuse downward some 16 to 18 inches, upward to the surface of the soil, and horizontally 8 to 10 inches. Usually it is not advisable to treat the soil immediately after plowing under a considerable amount of plant debris, or a covercrop. Often it is advantageous to fill in the grooves made by the chisels drilling in the fumigant by using a drag behind the applicator, or by using a round roller. With shallow-seeded crops, such as lettuce, seeding can be done 10 to 15 days after treatment. If a strong odor of the fumigant is detected in the soil, planting should be deferred. With beans it is better to wait 20 to

25 days after treatment especially in heavier types of soils. The planting date will depend upon the soil type and upon the moisture content at the time of treatment and thereafter.

In California, soil can be treated for wireworms throughout most of the year; however, in nearly all areas treatment is not possible during parts of December, January, and February, when the soil is too wet to work into a mellow condition.

The simultaneous application of anhydrous ammonia with D-D, using 35 pounds of ammonia per acre, was found advantageous in the Salinas Valley as a fall treatment when lettuce was to be



Fig. 6.--Results of treating wireworm infested soil in a field at Salinas: foreground, untreated 30-foot strip showing ravages of wireworms; immediate background, an area treated with 400 pounds D-D per acre.

planted. For carrots it is better not to use ammonia; otherwise an increased top growth may occur.

Warning: D-D should not be allowed to touch the skin; if it should come in contact with the skin, it should be immediately washed off with soap and water. Prolonged exposure to the fumes should also be avoided. If it is spilled upon clothing or shoes, the articles should not be worn.

#### Ethylene Dibromide Solution (EDB)

In experiments, ethylene dibromide solution<sup>3</sup> not only has proved to be very toxic to wireworms, but also to have value in controlling certain nematodes and other soil insects. Its value for the control of other soil organisms and soil pathogens is still to be determined.

The properties of ethylene dibromide (or 1,2-dibromoethane) are as follows:

Color and state . . . . .	colorless liquid
Specific gravity . . . . .	2.17
Pounds, per U.S. gallon . . . . .	18
Boiling point, degrees centigrade . .	131.6
Solubility in water, per cent weight (approximate) . . . . .	0.4

Ethylene dibromide is supplied as a 10 per cent (by volume, or 20 per cent by weight) solution dissolved in a naphtha 200-base thinner.

EDB can be applied to garden plots, seedbeds, or in a greenhouse by means of a hand applicator, such as was mentioned in the section under D-D; or it can be applied to field plots with a special field applicator (fig. 7). This machine can treat about 20 acres a day. At 12-inch intervals, using 20 gallons of 10 per cent EDB (by volume) per acre, the individual shot with the hand applicator is about 2 milliliters (cubic centimeters).

According to tests conducted to date in the field, 2 to 4 gallons of technically pure ethylene dibromide per acre are needed to control wireworms, the amount depending upon the soil type, soil texture, soil moisture, and other factors. In general, the soil should be in good friable condition, as mentioned under the section on D-D, and not too wet or too dry. EDB should be used before a crop is planted. It is best to wait 7 to 15 days before planting, although with beans and certain other crops immediate planting is often possible with no damage. Certain plants, such as tomatoes, may be injured if set out too soon after the soil treatment.

The present cost of EDB applied, using 20 gallons of the 10 per cent (by volume) EDB-thinner solution, is \$40 per acre.

As with D-D, it is better not to treat with EDB immediately after the plowing under of weeds, debris, or a covercrop. The treatment is most effective at temperatures above 45°F. The spacing of the points of injection should

not be greater than 12 inches, and the depth of injection should be 6 to 8 inches. EDB, when applied at 6 to 8 inches in the soil, diffuses downward 6 inches, upward to the surface, and laterally about 6 inches.

Warning: Prolonged exposure of EDB to the skin should be avoided. Following exposure, the hands should be washed thoroughly with soap and water.

It should be brought to the attention of those using or contemplating the use of D-D or EDB, for the control of wireworms, that these are

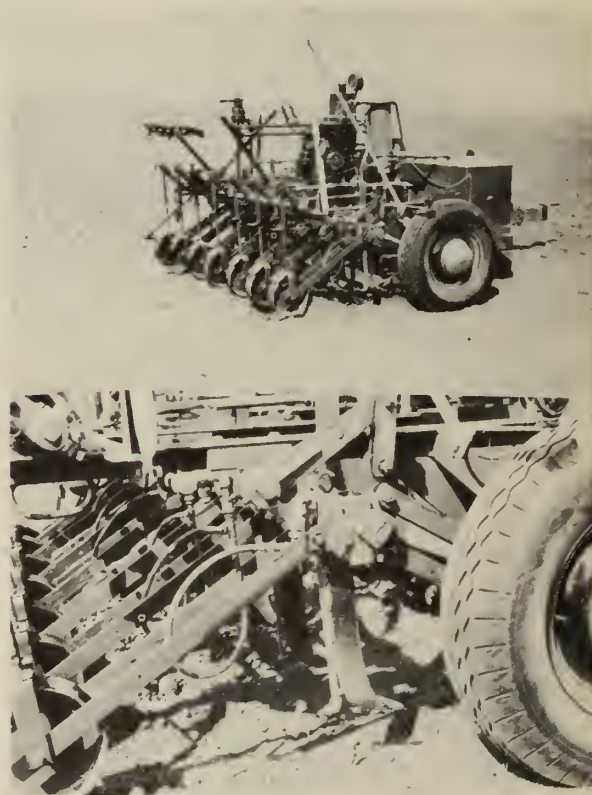


Fig. 7.--Equipment for applying ethylene dibromide mixture: upper, general view; lower, close-up of drills and packing wheels.

new chemicals and that their continued use on an experimental and commercial basis will perhaps yield further specific and other valuable information. Although satisfactory results have been obtained with these fumigants, when used at any time of the year the soil can be worked into good condition, it may be that optimum results can be obtained in a particular locality only at certain times of the year. There is also some evidence that different crops do not react in the same manner to these two fumigants. The lasting effect of a single treatment can be determined only by observing treatments for several years in regard to both wireworm populations and crop yields, although in a number of experimental and commercial applications the cost of the fumigant has more than been compensated for in the increased yields of a single crop following the treatment.

<sup>3</sup>The chemical used was supplied by the Dow Chemical Company of Midland, Michigan.